

Summary Report for Year 2 of

GEOPHYSICAL VALIDATION ACTIVITIES IN SUPPORT OF AIRS

Principal Investigator: Dr. Robert Atlas  
Laboratory for Atmospheres  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771

Co-Investigator: Dr. Joanna Joiner  
Global Modeling and Assimilation Office  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771

Submitted: April 7, 2004

## 1. INTRODUCTION/RESEARCH OBJECTIVES

The objective of this research is to conduct a detailed geophysical validation of AIRS data products, with the goal of improving the impact of AIRS data on both weather prediction and scientific investigations. Specific objectives include: (1) determining the accuracy and error characteristics of AIRS level 1B radiances, temperature and humidity retrievals, clouds and ozone, (2) determining the meteorological characteristics associated with reduced accuracy in AIRS data, (3) assessing the initial impact of AIRS data on atmospheric analyses and numerical weather prediction, (4) providing feedback to the AIRS Science Team to improve the AIRS data products, and (5) developing methodology to improve the utilization of AIRS data in atmospheric models.

## 2. SUMMARY OF WORK PERFORMED

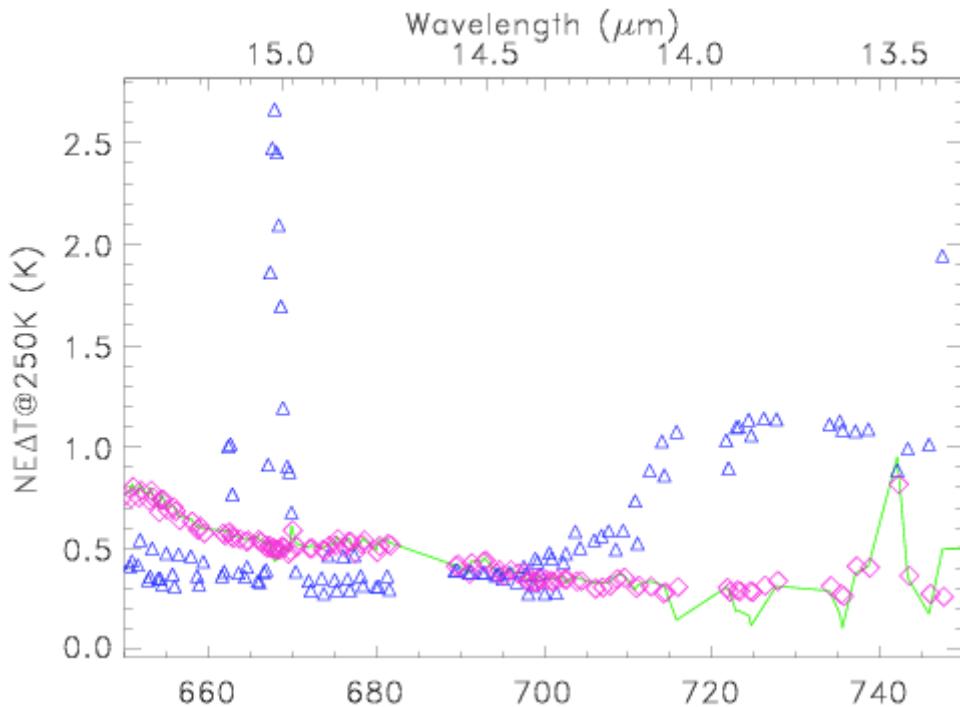
The geophysical validation that we have performed for AIRS over the last two years has included: the generation of high resolution comparison data sets using ACARS and other available data; collocations of AIRS data with in situ observations and global and regional analyses; computation of radiance departures from both forecast and assimilated temperature, humidity, and ozone fields; synoptic evaluation of AIRS fields by highly skilled meteorological analysts; objective quality control using the high resolution GEOS data assimilation system (FVDAS); and data impact studies in which different types of AIRS data were assimilated using several different data assimilation systems. The above validation activities were performed in close cooperation with AIRS Science Team members and have provided timely feedback to the team to enable improvements to AIRS data products, and have already led to improved impact of AIRS on atmospheric analyses and weather forecasts. A limited sample of results from the validation are provided below. More detailed results are available in powerpoint presentations on the AIRS Team website and in the references.

### Radiance Validation

We developed a method to estimate the random errors from the AIRS instrument (presumably due to detector noise) and separate those errors from background errors using observed minus background (O-B) brightness temperatures. The method is described in detail as an appendix in Joiner et al. (2004). The general idea

is that by averaging adjacent pixels, the random error variances will decrease by the square root of the number of pixels being averaged while background errors will not be reduced. Therefore, the approach works only when the atmosphere/surface of the adjacent pixels is homogeneous. This is the case for channels in  $15\mu\text{m}$  CO<sub>2</sub> band that have little or no contribution from the surface. Window channels and those that have significant water vapor absorption cannot be evaluated with this approach due to small-scale water vapor and surface variations.

The results will be briefly summarized here. Figure 1 ( $15\mu\text{m}$  band) shows the estimates of random noise (solid line) and background error (triangles) from this approach. All values are given in terms of (noise) equivalent temperature at 250K ([NEDT@250K](#)). The values of the random error are extremely consistent with the estimates of detector noise from the AIRS science team (diamonds). This gives us confidence in our estimate of background errors (projected to brightness temperature). Channels peaking in the upper stratosphere (near the  $15\mu\text{m}$  band center) and lower troposphere (short-ward of about  $14.3\mu\text{m}$ ) have significantly lower estimates of detector noise than the forecast errors. This suggests that AIRS data, if properly used, should be able to add information to an assimilation system. The channels peaking in the upper troposphere and lower stratosphere (around 660 and  $680\text{cm}^{-1}$ ), in contrast, have detector noise estimates slightly higher than projected forecast errors. Even though the detector noise is higher than the projected background errors for these channels, there are many that have more-or-less redundant weighting functions. In this case, using the redundant channels has the effect of reducing the random noise component so that all the channels used together will still add information to a data assimilation system.



## Validation of temperature and humidity retrievals and clouds

The validation of AIRS temperature and humidity retrievals and clouds that we are performing consists of four major elements. The first component of the validation have been synoptic evaluations by highly skilled meteorological analysts. This was used to determine that the initial AIRS fields were reasonable from a meteorological perspective and also the extent to which the AIRS data are in general agreement with other meteorological observations. The second component of the validation has been the generation of collocation statistics to assess quantitative accuracy. AIRS temperature retrievals have been compared with temperature observations from rawinsondes, ACARS, and with both GEOS and NCEP model analyses. Similar comparisons for AIRS moisture profiles are beginning. In addition, AIRS derived total precipitable water will be compared with SSM/I and TMI observations, and AIRS cloud products will be compared with surface observations of clouds, geostationary satellite observations, and dewpoint depressions measured by rawinsondes. The third component of the validation is the objective quality control of the provided by GEOS and FVSSI DAS. These results are related to meteorological conditions and fed back to the AIRS Team in order to improve both the accuracy of the AIRS data and the reliability of its internal quality assessment. This is an iterative process and is currently being restarted to assess the new AIRS quality flags. The fourth component of our validation consists of Observing System Experiments (OSE). Observing system experiments have been and continue to be conducted to evaluate the impact of AIRS data and to contribute to their improved utilization. The effect of AIRS data on analyses is evaluated in terms of the magnitude, location, and structure of large-scale differences between analyses with and without the data. In addition, differences in the location and intensity of specific synoptic and sub-synoptic features, including cyclones and convergence zones, are evaluated. The impact on numerical weather prediction is evaluated objectively using rms differences, correlation coefficients and objective storm-tracking techniques. Subjective comparisons of forecast differences have also been performed to assess the meteorological significance of forecast impacts. The final component of the evaluation are detailed case studies to better understand the nature of the impact.

## Results from Forecast Impact Experiments

Under this proposal, we are evaluating the impact of AIRS data in several forms: clear vs, partially cloudy data, AIRS Team physical retrievals, 1-D Var interactive retrievals, and AIRS radiances; and are using several different DAS for this purpose. Results are presented here for

three sets of experiments in which data was assimilated using the FVSSI DAS for the period January 1 – January 31, 2003. Five day forecasts were run every two days beginning January 6, 2003 and forecasts every 12 hours were verified against the NCEP analysis, which was taken as “truth”. In the first experiment, called “control”, all the data used operationally by NCEP was assimilated, but no AIRS data was assimilated. The operational data included all conventional data, TOVS and ATOVS radiances for NOAA-14, 15, and 16, cloud tracked winds, SSM/I total precipitable water and surface wind speed over ocean, QuikScat surface wind speed and direction, and SBUV ozone profiles. In the second and third experiments, called “clear AIRS” and “all AIRS”, temperature profiles retrieved from AIRS soundings were assimilated in addition to the data included in the “control” experiment. “Clear ocean” included all accepted temperature retrievals derived from AIRS over ocean and sea ice in cases where the retrieved cloud fraction derived from AIRS was less than or equal to 2%, while the “all ocean” experiment assimilated accepted AIRS temperature soundings over ocean and sea ice for all retrieved cloud fractions.

Figure 2 shows anomaly correction coefficients of forecast sea level pressure verified against the NCEP analysis for both Northern Hemisphere extra-tropics and Southern Hemisphere extra-tropics for both the “control” and “all AIRS” experiments. In the Northern Hemisphere, addition of all AIRS soundings resulted in an improvement in average forecast skill of the order of 1 hour or less, but an improvement in average forecast skill in the Southern Hemisphere on the order of 6 hours results from assimilation of AIRS soundings. Assimilation of AIRS soundings under essentially clear conditions (not shown), resulted in somewhat poorer forecasts than using all AIRS soundings. It should be noted that the Aqua orbit (1:30 ascending) is almost identical to that of NOAA 16 carrying HIRS3, AMSU A and AMSU B, so AIRS/AMSU/HSB soundings are providing additional information to that contained in the AMSU A/AMSU B radiances on NOAA 16 in the same orbit.

Figure 3 shows the RMS position error (km) and magnitude error (hPa) for 5 day forecasts of extra tropical cyclones in the three experiments. It is apparent that addition of AIRS soundings improved RMS forecast skill for both the position and magnitude of extra-tropical cyclones globally, and addition of AIRS soundings in partially cloudy areas further improved forecast skill as compared to use of soundings only in essentially clear conditions.

Several thousand cyclones verifications are included in these statistics. Addition of AIRS data did not improve forecasted cyclone position and intensity for each cyclone. Some were improved substantially however. Figure 4 shows the impact of AIRS data on the 24 hour

forecast of position and intensity of tropical storm Beni, which was centered roughly 4° east of New Caledonia on January 31, 2003 with a central pressure of 990 mb

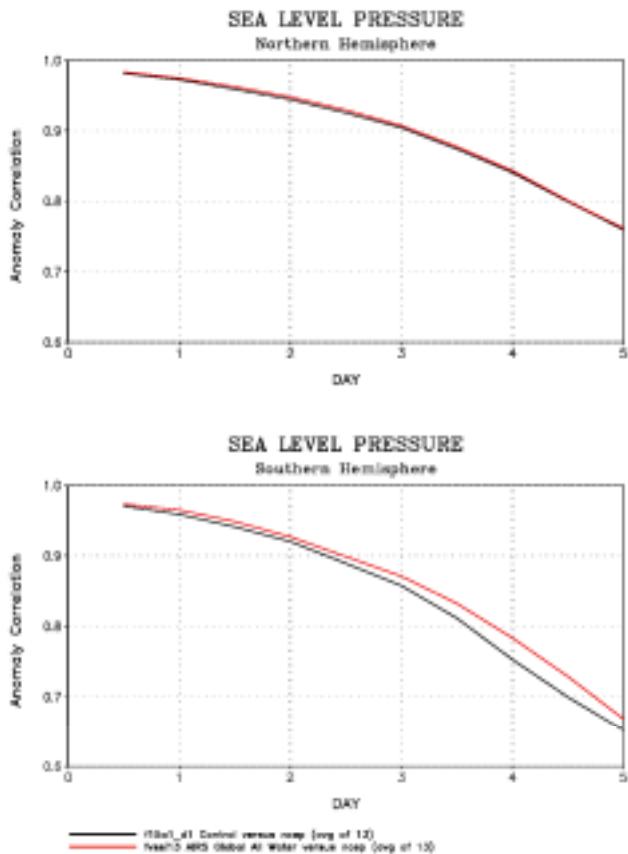


Figure 2

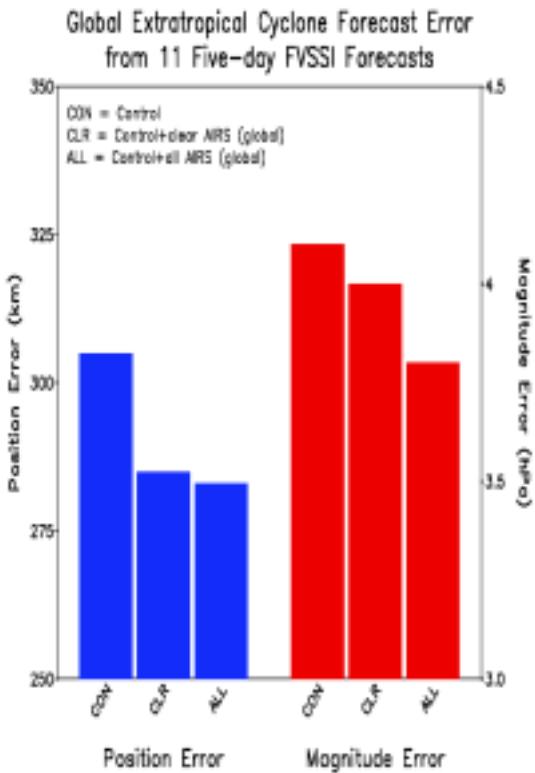


Figure 3

Figure 4d). The control forecast (Figure 4a) produced a relatively weak cyclone (1007 mb) displaced considerably to the northwest, while the 24 hour forecast using AIRS data (Figure 4b) was much more accurate in both position and intensity (995 mb). It is significant to note that our forecast using AIRS data was more accurate in both position and intensity than the NCEP operational forecast (Figure 4c) in this case, which, even though it used a higher resolution model and analysis system, did not have the benefit of AIRS data. The results shown indicate the potential of AIRS soundings to improve operational forecast skill. We are working with NCEP to arrange an experiment to add AIRS temperature soundings to an otherwise equivalent run on the NCEP computing system to see the extent, if any, that operational forecast skill can be improved upon.

## Impact of AIRS on 24hr Forecast of Sea Level Pressure

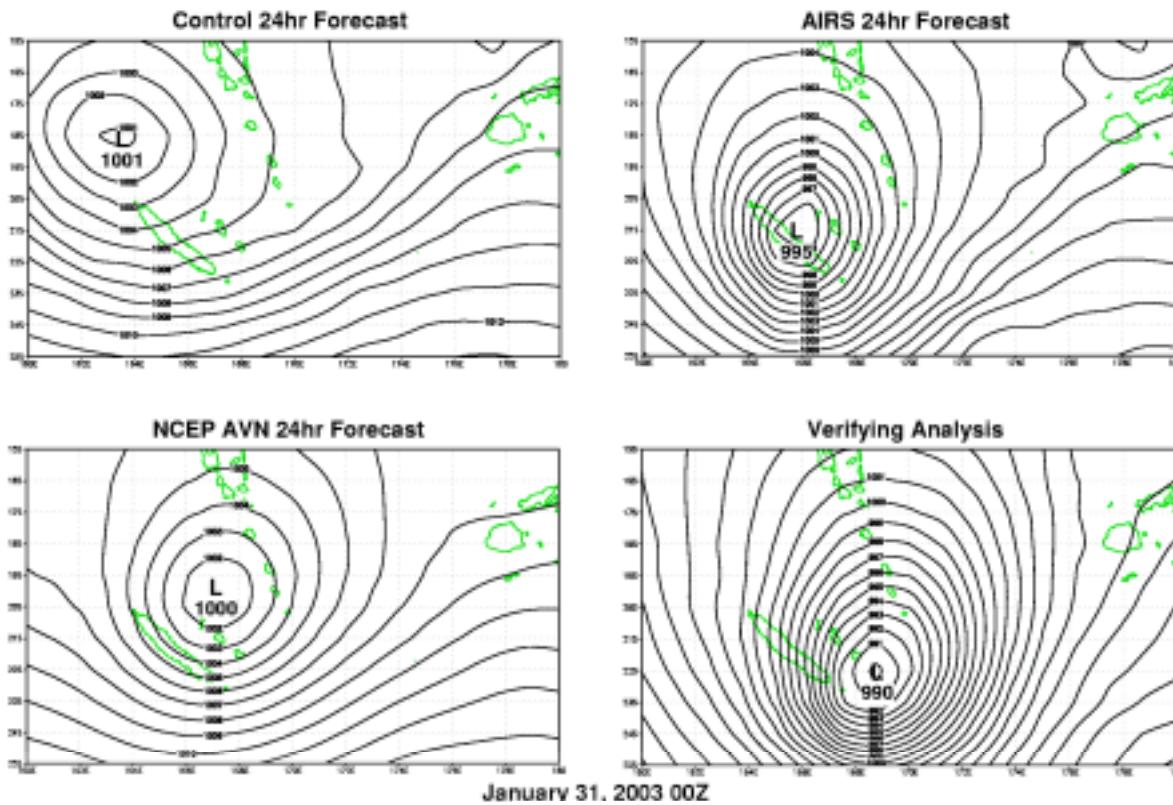


Figure 4

## References

Atlas, R., E. Brin, J. Jusem, J. Terry, O. Reale, J. Ardizzone, and D. Bungato, 2004: the initial impact of AIRS retrievals on FVGCM forecasts. To be submitted.

Joiner, J., Poli, P., Frank, D., and H.-C. Liu (2004). Detection of cloud-affected AIRS channels using an adjacent-pixel approach. Quart. Roy. Meteor. Soc., accepted.

Lin, S.J., R. Atlas, and K. S. Yeh, January-February, 2004. Global weather prediction and high end computing at NASA. *Computing in Science and Engineering*, 29-35.

Susskind, J., R. Atlas, C. Barnet, J. Blaisdell, L. Iredell, E. Brin, J.C. Jusem, F. Keita, L. Kouvaris, G. Molnar, 2004. Current results from AIRS/AMSU/HSB.